LUNAR HOLES AND THEIR ASSOCIATED SUBSURFACE CAVERNS: FROM SELENE (KAGUYA) TO UZUME. Junichi Haruyama [1], Isao Kawano [1], Toshiyuki Nishibori [1], Takahiro Iwata [1], Yukio Yamamoto [1], Kazuhito Shimada [1], Keiko Yamamoto [1], Toshiaki Hasenaka [2], Tomokatsu Morota [3], Masaki N. Nishino [3], Ko Hashizume [4], Motomaro Shirao [5], Goro Komatsu [6], Nobuyuki Hasebe [7], Hisayoshi Shimizu [8], Kensei Kobayashi [9], Shinichi Yokobori [10], Yohei Miyake [11], Yuichi Michikawa [12], Takeshi Tsuji [12], Reina Shinoda [1] [12]. [1]JAXA, Japan, [2]Kumamoto University, Japan, [3] Nagoya University, Japan, [4] Osaka University, Japan, [5] Planetary Geology Institute, Japan, [6] Università d'Annunzio, Italy, [7] Waseda University, Japan, [8] University of Tokyo, Japan, [9] Yokohama National University, Japan,[10]Tokyo University of Pharmacy and Life Sciences, Japan, [11] Kobe University, Japan, [12] National Institute for Environmental Studies, Japan, [13]Tokai University, Japan. E-mail:haruyama.junichi_at_jaxa.jp.

In 2009, three deep pits, gigantic vertical holes, that have aperture diameters and depths of several tens of meters to one hundred meters were discovered in the data of Terrain Camera (TC) onboard Selenological and ENgineering Explore (SELENE, nicknamed KAGUYA)[1,2](Fig.1). These holes are located in Marius Hills, Mare Tranquillitatis, and Mare Ingenii. They are possibly "skylights" opened on subsurface caverns such as lava tubes. Similar hole structures are also found on Mars [3,4].

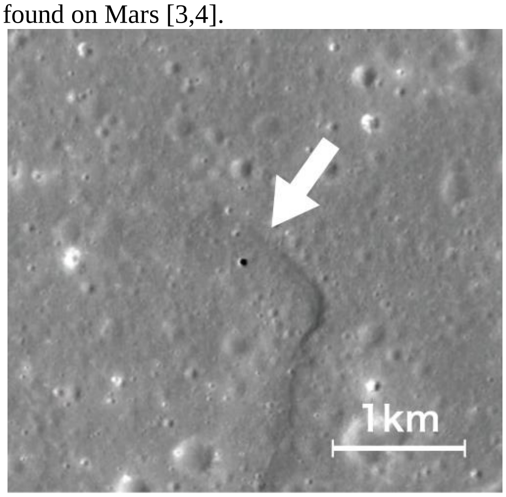

Fig.1 A hole, possible possible skylight of a undersurface cavern, discovered in Mairus Hills on the Moon.

The United States Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) which resolution is ten times better than that of TC later identified more pits on the Moon [2,5-7], including three holes that SELENE TC had discovered. Wagner et al. (2014) [7] classified the pits into three types based on their locations: floors of large craters, mare, and highlands. The pits on the crater floors were possibly formed by depression and/or degassing of cooling impact-melt lavas. Most are smaller than a few tens of meters in diameter and are not skylights of subsurface caverns. Eight pits including that SELENE TC discovered were identified in mare regions.

"Pit" is a general term for depression structures. However, vertical holes that SELENE TC discovered are apparently unique, different from other smaller and shallower depressions [8]. Thus, we adopt the term "hole" to refer to possible skylights of undersurface caverns, such as the Marius Hills Hole (MHH), Mare Tranquillitatis Hole (MTH), and Mare Ingenii Hole (MIH).

Subsurface caverns are quite safe shelters for long-term manned/unmanned activity on the Moon; humans/machines can escape from impacts of numerous meteorites, constantly showering radiation, and widely oscillating temperature in the caverns. They are the best places for constructing lunar bases. Lunar holes are possible entrances to the caverns. The discovery of lunar holes has opened a new era for humans to explore the Moon and go beyond it.

Lunar holes and their associated subsurface caverns could be regarded as resources for lunar science[2]. They are places where (1) fresh materials are easily observed and sampled in the holes and caverns and (2) are entrances to caverns that provide a safe, quiet environment. Furthermore, exploring the lunar caverns through the deep vertical holes will provide good lessons for exploring Martian holes where we will be able to acquire information of the Martian geologic history and to establish bases and where extraterrestrial life may survive.

We present a summary of lunar holes and associated caverns. Furthermore, we also introduce the project Unprecedented Zipangu Underworld of the Moon/Mars Exploration (UZUME) [9] to explore the holes and caverns.

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